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Mark-recapture estimates of non-Sable Island grey seal *(Halichoerus grypus)* pup production

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Abstract

Grey seal pup production in the Gulf of St. Lawrence was estimated for the 1984-1986 and 1989-1990 seasons using Petersen mark-recapture methods. Pup production based on mark-recapture estimates from shot samples collected from Anticosti Island ranged from 4,625 (±1,247) to 6,681 (±2,215) for 1984 to 1986. Estimates based on the live-recapture on Sable Island of pups tagged in the Gulf resulted in a pup production of 5,233 (±1,249) to 9,618 (±2,953) for 1984-86, and 12,349 (±4,454) and 8,316 (±1,705) for 1989 and 1990 respectively.

Résumé

La production de jeunes phoques gris dans le golfe du Saint-Laurent a été estimée pour les périodes 1984-1986 et 1989-1990 à l'aide de la méthode de marquage-recapture de Petersen. La production de jeunes, établie d'après les estimés de marquage-recapture provenant d'échantillons de phoques tués à l'île d'Anticosti, variait de 4,625 (±1,247) à 6,681 (±2,215) entre 1984 et 1986. La production estimée à partir des opérations de recapture à l'île de Sable de jeunes phoques vivants marqués du golfe, variait de 5,233 (±1,249) à 9,618 (±2,953) entre 1984 et 1986, et s'élevait à 12,349 (±4,454) et 8,316 (±1,705) en 1989 et 1990, respectivement.

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Introduction

Grey seals have been identified as a major host of the anisakid parasite, *Pseudoterranova decipiens*, which infects commercial fish species and must be removed during processing (Templeman 1990). Recent diet information suggests that grey seals may compete with commercial fishermen through the consumption of commercially important fish species (Benoit and Bowen 1990a,b)

In Canada, there are two large breeding concentrations of grey seals. The most intensively studied concentration breeds on Sable Island approximately 160 km off the Nova Scotia coast (Mansfield 1966; Mansfield and Beck 1977; Stobo and Zwanenburg 1990; Zwanenburg and Bowen 1990), while a second large concentration breeds on the pack ice in the southern Gulf of St. Lawrence (Mansfield 1966). Other small groups of whelping animals are found on Bowen's Ledge and Big White Island off eastern Nova Scotia, and on Amet Island and Deadman Island in the Gulf of St. Lawrence (Mansfield and Beck 1977).

Based on complete enumeration, 9,712 pups were born on Sable Island in 1989 (Stobo and Zwanenburg 1990). Modelling of population trends using a combination of estimates of Sable Island pup production, and vital rates from hunted samples indicates that this segment of the population is increasing at a rate of 12.5% per year or doubling roughly every 6 years (Zwanenberg and Bowen 1990).

Less is known about non-Sable Island pup production due to logistical difficulties associated with working on drifting pack ice. Previous estimates from several mark-recapture experiments have indicated that pup production during 1984-86 could be as low as 5,295 based on the recovery of tags in scientific collections from Anticosti Island, or as high as 11,694 animals based on the resighting of tagged and untagged pups from the Gulf that had migrated to Sable Island during the spring (Stobo and Zwanenberg 1990). The wide range in these estimates suggests that several assumptions essential to the Petersen estimator were violated and it was concluded that the true population size likely lay in between the 2 estimates (Stobo and Zwanenberg 1990).

In this paper we refine mark-recapture estimates of 1984-1986 pup production in the Gulf of St. Lawrence using a larger sample of animals from Anticosti Island and compare these estimates with those obtained from the live-capture of pups on Sable Island (Stobo and Zwanenberg 1990). We also present estimates of 1989 and 1990 pup production based on the resighting of pups on Sable Island.

Materials and Methods

Study area

The study area included eastern Northumberland Strait, St. George's Bay, and the western coast of Cape Breton Island. Except for small pupping colonies on Amet Island and on Deadman Island, the majority of pups are born on the pack-ice in Northumberland Strait and St. George's Bay (Fig 1). Ice formation begins during the middle of December along the eastern New Brunswick coast and in Northumberland Strait. This ice drifts towards the east into St. George's Bay or across the top of St. George's Bay, and northwards along the west

coast of Cape Breton exiting via Cabot Strait into the Atlantic Ocean (Markham 1980). Ice stability depends on local wind conditions. Although the prevailing winds are westerly (Markham 1980), sudden shifts to the northwest, will move ice into St. George's Bay, while changes to southerly winds can clear St. George's Bay overnight (M.O.H. personal observation).

The location of large concentrations of grey seals is dictated largely by the availability of suitable ice for whelping. Grey seals appear to prefer rafted pack ice 40 to 80 cm thick.

Small pupping colonies (N < 150) occur on Amet Island and Deadman Island (Fig 1). Pupping at these locations begins in late December. Pupping on the ice begins in early January. The buildup in number of births occurs rapidly with 65% of the births occuring by 23 January. However, the season of births is prolonged with newborn pups still appearing on the ice in early February.

Mark-recapture experiment

Grey seal pups were marked with a uniquely numbered tag prior to weaning on the pack-ice in the southeastern Gulf, on Amet and Deadman Islands in the southern Gulf of St. Lawrence, and on the eastern Nova Scotia shore during 1984 (N=1,423), 1985 (N=2,242), 1986 (N=1,681), and 1989. In 1989, 2,723 tags were applied in the Gulf (N=2,551) and along the eastern shore of Nova Scotia (N=172). Late ice break-up and good hunting conditions resulted in 1,612 pups being killed before May, including 718 tagged pups. This reduced the effective number of tags to 2,005. In 1990, only pups born on the pack-ice and on Amet Island were tagged (N=2,226). Pups were marked with a single numbered tag in 1984 and 1990, double tagged in 1986 and single or double tagged in 1985 and 1989.

For all recaptures, animals were examined for the presence of a tag or evidence of tag loss. Tags recovered from animals born on Sable Island were removed from the recapture totals. Lower jaws were removed from shot samples and age determined by three readings of a cross-section of a lower canine tooth (Mansfield 1991).

In the first experiment, recaptures were from shot samples obtained as part of scientific collection programs undertaken on Anticosti Island during June-August 1986, 1987 and 1988.

In the remaining experiments all recaptures were completed on Sable Island. There, virtually all pups have been tagged between 1977 and 1990. Randomly allocated transects completed in late January-early February 1990 through the fasting pup concentrations on Sable Island indicated that <2 % of the Sable Island born pups were untagged. Consequently, among the recaptures of untagged pups the total count was reduced by 2% to compensate for the fraction of pups born on Sable Island that were not tagged. All remaining untagged animals were assumed to have been born in the Gulf or along the eastern shore of Nova Scotia.

In the first experiment conducted on Sable Island, several surveys were completed to live capture pups after they had hauled out on the beach during March-August 1984, 1985, 1986, 1989 and 1990. In a second experiment, a sample of yearlings was also shot on Sable Island during January-February 1986.

Pup production was determined using a modified Petersen estimator (Chapman 1951) where pup production (N) is;

$$N = \frac{(M + 1)\ (n + 1)}{(m + 1)} - 1$$

The variance of the estimate (Var(N) and 95% confidence estimates were calculated from;

$$Var\,(N) = \frac{(M + 1)\ (n + 1)\ (M - m)\ (n - m)}{(m + 1)^2\ (m + 2)}$$

$$and \qquad N \pm 1.96\ \sqrt{Var\ (N)}$$

Uniformity of tag mixing between the samples was examined using a Chi-square test of independence (Siegel 1956), by comparing the relative frequency of tagged and untagged animals in the recapture samples. A second analysis used a Chi-square test of independence to compare the number of tags applied at different colonies and in the first (early) and second (late) halves of the tagging season to the relative frequency of tag recoveries from different colonies and from early and late applied tags in the tag recovery sample.

Results

Anticosti Island mark-recapture experiment

A total of 132, 100 and 100 animals from the 1984, 1985 and 1986 cohorts were shot during the scientific collections undertaken at Anticosti Island in 1986, 1987 and 1988. Included in this total are 11, 10 and 13 animals that had been tagged on Sable Island. Tag loss was minimal. One tag was lost from each of the 1984 and 1985 shot samples from Anticosti Island. Since Sable Island tags accounted for $<13\%$ of the recoveries, animals that had lost tags were assumed to have come from the Gulf. Consequently the number of Gulf tagged animals was increased by 1 (Table 1).

During 1984-86, tags were applied in both the Gulf and along the Nova Scotia eastern shore. Eastern shore tags accounted for 1%, 6% and 9% of the tags applied in 1984, 1985 and 1986 respectively. In the recoveries from Anticosti Island, eastern shore tags represented 0%, 0%, and 7% of the recoveries from 1984, 1985 and 1986 respectively, but the number of tags was too small to determine if these differences were statistically significant.

No significant differences were found amongst the tag recoveries in the relative frequencies of tagged and untagged animals (Table 1) or in the relative frequencies of tags applied early and late in the season for the 1984, and 1985 cohorts sampled from Anticosti Island. In the 1986 cohort, tags applied late in the season were over-represented in the 1987 and 1988 samples ($X^2=4.6$, $df=1$, $p<0.05$). Consequently, the 1987 and 1988 recoveries were excluded from the analysis, and 1986 pup production was calculated using only animals aged $<$ 1. Grey seal pup production for 1984-86 based on the shot samples from Anticosti Island was 4,625 ($\pm$1,247) to 6,681 ($\pm$2,215) animals (Table 2).

Sable Island mark-recapture experiment

Beach surveys were conducted repeatedly during March-October 1984-1986 to obtain information on the number of non-Sable Island tagged and untagged pups present on the island (Table 3). The appearance on Sable Island of pups born in the Gulf appears to be affected by ice drift. In 1984, there was little ice drift out of the Gulf, consequently the proportion of Gulf tagged animals recaptured on Sable Island remained low. In 1985, heavy ice drifted to within 32 km of Sable Island, resulting in a higher proportion of non-Sable Island pups in the recapture surveys (Stobo and Zwanenburg 1990).

Compared to the Anticosti Island sample, tags from the eastern shore were more prevalent in samples obtained from Sable Island, representing 1% of the recoveries from 1984, 14% of the Sable Island recoveries in 1985 and 13% of the recoveries from 1986.

No significant differences were observed in the proportion of tagged animals or in the proportion of early and late tags in the 1984 Sable Island recoveries (Table 3). Pup production was estimated to be 6,661 ($\pm$2,129) animals (Table 2).

In 1985, no significant differences were observed between samples in the proportion of tags recovered. However, in the sample from May, tags applied early in the season were over-represented in the recapture sample ($X^2=4.4$, $df=1$, $p<0.05$). Similarly, eastern shore tags appeared to be over-represented in the May-June samples accounting for 14% (N=27) and 13% (N=23) of the May and June recoveries respectively, instead of the expected 6% as indicated by the distribution of tagging effort. Pooling of the May-June samples, indicated that the eastern shore samples were indeed over-represented ($X^2=5.8$, $df=1$, $p<0.05$). Due to differences found in the distribution of tags in the May-June samples and the small size of the samples from the remaining months a reliable pup production estimate could not be calculated from the 1985 live capture recovery data.

In the sample of yearlings shot on Sable Island during January-February 1986 pup production was estimated to be 5,233 ($\pm$2,447) animals (Table 2). However, in this sample 2 of 8 tags were from the eastern shore, suggesting that this area was over-represented in the recovery sample. This was not examined further due to the small sample size.

In 1986, no differences were observed between samples in the proportion of tagged animals or in the representation of early and late applied tags in the recovery samples. However, a significantly greater than expected number of tags from the eastern shore (N=6) were observed in the 26 May-1 June sample ($X^2=10.8$, $df=1$, $p<0.05$). This sample was discarded and pup production was recalculated using just the 3-9 May sample resulting in an estimated pup production of 9,618 ($\pm$2,953)(Table 3) for 1986.

Sable Island mark-recapture experiment: 1989-90 pup production

Grey seal pups were captured, examined for tags and released on Sable Island during May-June 1989 and May 1990 (Table 4). Analysis of the frequency of Gulf tags applied early and late in the season in the recaptures showed that there were a greater than expected number of tags applied late in the season, in the June recapture sample ($X^2=5.3$, $df=1$, $p<0.05$). Consequently, pup production was estimated using the May sample only (Table 4). In the May recapture sample, 4 animals had lost tags. We assumed that tag loss between Sable Island and Gulf tagged animals was similar and that all untagged animals were of Gulf origin. We also assumed that Gulf animals account for only 17% of the total number of

recaptures. This assumption is not unreasonable since 4 double tagged animals from the Gulf, captured in the May sample had not lost any tags. Total pup production was estimated as 10,737 (±4,454) animals. Adding in the animals killed early in the spring results in an estimated pup production of 12,349 (±4,454).

In 1990, 2,219 tags were applied in the Gulf. No tags were applied on Deadman Island in the southern Gulf of St. Lawrence or along the Nova Scotia eastern shore. A total of 770 pups were captured, including 524 from Sable Island, 238 pups of non-Sable Island origin and 8 pups of unknown origin due to lost tags (Table 4). Tags applied early in the season and tags applied late in the season were equally represented in the May 1990 Sable Island recapture sample. Total pup production was 8,315 (±1,705) assuming that all of the pups that had lost tags were of Sable Island origin. Since non-Sable Island pups represented 32 % (N=774) of the total number of recoveries, if the same proportion of lost tags were assumed to be from non-Sable pups (2 of 8), the resulting non-Sable Island pup production estimate was 8,130 (±1,634).

Discussion

Mark-recapture techniques have been used successfully to census pinniped populations (Bowen and Sergeant 1983; Chapman and Johnson 1968). Logistically they are relatively easy to complete, but difficulties are encountered in trying to satisfy model assumptions, and in obtaining sufficient marks during the recapture phase.

In our mark-recapture study we used the Petersen method to estimate pup production because of its simplicity and its relative robustness to violations of model assumptions. We relied on samples from scientific collections and live-captures on Sable Island for tag returns because there is currently no commercial hunt for grey seals, and returns from the bounty hunt are considered to be unreliable (Zwanenberg 1984). Application of the Petersen estimator assumes that mortality of marked and unmarked animals is similar, there is no emigration or immigration, tags do not affect an animal's catchability, tags are not lost, all animals have an equal probability of being marked and the distribution of tags in the recovery sample are uniform (Seber 1982). Our analysis of the distribution of tag recoveries showed that some tags were unequally represented in the recovery sample. This unequal distribution of tags was responsible for the wide range in the previous estimates of non-Sable Island pup production 5,295-11,694 animals (Stobo and Zwanenburg 1990). Exclusion of these samples from the estimation procedure still resulted in estimates of 4,625 to 9,618 animals for non-Sable Island pup production for 1984-86. However, both the low estimate of 4,625 pups from the Anticosti Island experiment which is based on animals aged < 1 year, and the high estimate of 9,618 pups from the Sable Island experiment were for 1986 pup production. Since both estimates for the same year are moving in opposite directions it is likely that the 1986 pup production estimates are less reliable than the estimated pup production for the remaining 2 years. Furthermore, it appeared that tags from the eastern shore of Nova Scotia were over-represented in the small 1986 shot sample of yearlings from Sable Island. Excluding these samples, we conclude that non-Sable Island pup production during 1984-1985 was between 6,378 (±1,740) and 6,681 (±2,215) animals.

Estimates of non-Sable Island pup production for 1989-90 were 8,316 to 12,349

animals including animals removed during the May hunt in 1989. These estimates are similar to estimates of 8,541 (±1,378) to 11,403 (±1,884) obtained from a within season mark-recapture experiment conducted on the whelping patch during January and February 1989 and 1990 (Myers et al. 1992). The estimates from the within season mark-recapture model are not strictly comparable because they are estimates for pup production on the ice only, while estimates from the Sable Island experiments may also include animals born on the eastern shore of Nova Scotia, and Deadman and Amet Islands in the Gulf. Based on our tagging efforts in other years pup production in these areas would account for <500 animals (Hammill unpubl. data).

Our analysis indicates that non-Sable Island grey seal population has likely increased since the 1984-86 study was completed. However, given that only 2 point estimates are available with relatively wide 95 % confidence limits, it is difficult to assess the rate of population growth at this time. During the summer of 1992, scientific collections on Anticosti Island were completed. These should provide additional samples to estimate 1989 and 1990 pup production, for comparison with estimates of pup production obtained in 1984-1986.

Combining estimates of 1989-90 pup production of 9,712 for Sable Island (Stobo unpublished data), and the mean for the estimates of 8,316 to 12,349 for non-Sable Island pup production results in a total pup production of 20,044 animals and a total population estimate of 112,249 animals for the Northwest Atlantic grey seal assuming a 1+ to pup ratio of approximately 5.6 (Zwanenburg and Bowen 1990).

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Table 1. Recoveries of tagged and untagged animals during sampling programs conducted at Anticosti Island.

Cohort	1984	1985	1986
Specimen Age	2 3 4	1 2 3	0 1 2
Tags Recovered	14 3 7	18 7 5	31 10 3
Untagged Animals	61 20 16	32 18 10	56 19 10
Total	75 23 23	50 25 15	87 29 13

Table 2. Mark-recapture estimates (N) of non-Sable Island pup production during 1984-1986.The 1985 Sable Island estimate is from a sample of yearlings shot during Jan.-Feb 1986. [1] 1 tag has been added to account for tag loss.

Anticosti Island Sample

Year	Total Tags	Tags Recovered	Total Animals	N	SE	95% C.I.
1984	1423	25[1]	121	6681	1130	2215
1985	2242	31[1]	90	6378	888	1740
1986	1681	31	87	4625	636	1247

Sable Island Sample

1984	1423	27	130	6661	1086	2129
1985	2242	8	20	5233	1249	2447
1986	1681	31	182	9618	1506	2953

Table 3. Recoveries of tagged and untagged animals from Sable Island (after Stobo and Zwanenberg 1990).

Year	Date of Recapture	Non-Sable Tags	Untagged Animals
	2-5 Mar	1	5
1984	3-5 Apr	5	25
	3-6 May	10	20
	1-5 June	10	48
	4-12 Oct	1	5
	26-31 Mar	2	64
1985	4-8 May	30	139
	4-12 June	25	112
	10-17 Sept	3	12
1986 (yearlings)	Jan-Feb	8	12
	13-19 Mar	1	0
1986	3-9 May	31	151
	26 May-1June	23	130
	10-17 Sept	2	9

Table 4. Marked recapture estimates for 1989-90 pup production for animals recaptured on Sable Island. A total of 2,005 and 2,226 pups were marked in 1989 and 1990 respectively.

Year	Sable Tags Recovered	Gulf Tags Recovered	Untagged Pups	Tag Loss	N	SE	95% C.I.
1989							
May	442	16	74	4			
June	375	31	53	10	10737	2273	4454
1990	524	63	175	8	8316	870	1705

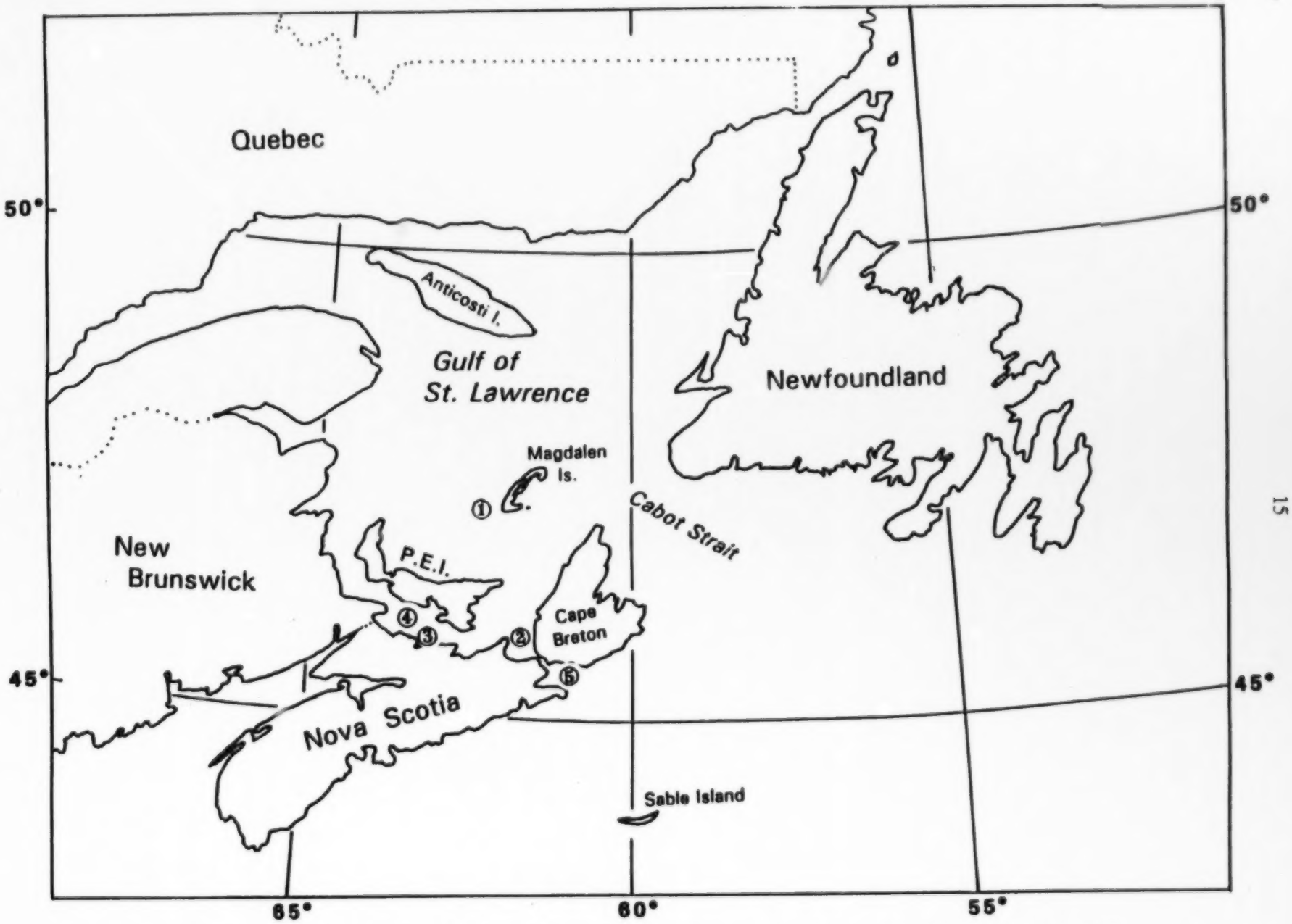

Fig. 1. Map of eastern Canada showing major grey seal pupping sites in the southern Gulf of St. Lawrence and on Sable Island, located 160 km to the east of Nova Scotia. 1 = Deadman Island; 2 = St. Georges Bay; 3 = Amet Island; 4 = Northumberland Strait; 5 = Bowen's Ledge & Big White Island